

8707.aaa.
AN
E P I T O M E

OF A
Course of Lectures

ON
NATURAL AND EXPERIMENTAL
P H I L O S O P H Y:

AS THEY ARE DELIVERED BY
J O H N B A N K S.

BY THE WORD OF THE LORD WERE THE HEAVENS
MADE: AND ALL THE HOST OF THEM BY THE
BREATH OF HIS MOUTH. PS. XXXIII. 6.

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MDCC LXX V.

(PRICE ONE SHILLING.)

THE T. O. M. E.

Count of Lorraine

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THE T. O. M. E.



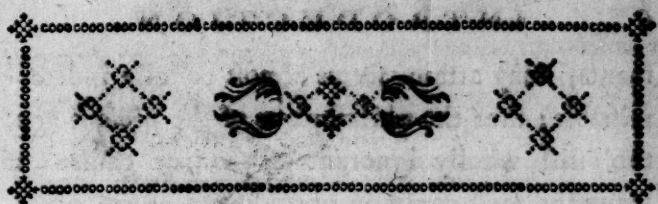


P R E F A C E.

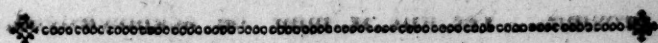
*A*T the request of a great number of my subscribers at different places, I have drawn up, with as much order and accuracy as time would permit, the following epitome; which is chiefly designed for the use of those who have attended my course of experiments; to such, I flatter myself, it will be found of great service, by recalling ideas which had slipped the memory; and the want of plates it is presumed, will be abundantly compensated by the apparatus; and to those who have not yet had the opportunity, it may, in some measure, convey the first principles

of the sciences, provided they will be content with naked assertions, without either mathematical demonstration, or experimental proof.





AN
E P I T O M E
OF A
COURSE OF LECTURES.



INTRODUCTION.

THIS course is intended to explain, in the most easy, and familiar manner, the general properties and laws of matter; and to set before the inquisitive mind, the causes of the most material phenomena which we observe amongst natural bodies; at least, so far as discovered; for though we must confess that the works of infinite wisdom can never be fully comprehended by the faculties of man, yet how far reason, when assisted with instruments

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ments, may attain, seems almost equally indeterminate; thus the philosophers of the present age, tho' still wholly ignorant of the true causes of many the most common phænomena, have nevertheless, by diligent enquiries and experiments, gained the knowledge of many equally unknown to our forefathers, and by them, perhaps deemed incomprehensible; and there is no doubt but in future ages, science will continue its progression. For it seems providentially appointed, as some way necessary for the carrying on, or well being of society, that the sciences should be gradually improving. Yet still it must be acknowledged, that many things are known, which reason could never have led us to the knowledge of: But whilst man has been diligently seeking after one thing, he has accidentally, or rather providentially, hit upon, or discovered another, of greater importance, and of more extensive utility to mankind.

As to the use of philosophy, it must be confessed to be almost unlimited, and may be recommended to people of all ranks. For many things appear to be, what in reality they are not. Thus to the eye, unassisted by philosophy, the sun appears to
be

be a flat shining plate, the stars to be small lucid points, like diamonds, and all at equal distances from us; and seem to revolve round the earth in twenty four hours, while the earth seems to be fixed, and to be by much the largest body in the universe. But a competent knowledge in philosophy will strip things of the disguise and false colours under which they appear; or rather instead, as is too commonly supposed, of contradicting the plain and positive proof of the senses, evince, to the most unanswerable demonstration, the impossibility of their appearing otherwise; and from those very appearances deduce the most convincing arguments to support its own assertions; thus will it furnish the mind with more just and sublime ideas, by removing the errors of prejudice, received by false education, custom, or the authority of men.

PHILOSOPHY also, as it is concerned in the invention and adjustment of machines, is of universal utility to mankind; to it we owe the construction of ships, steam-engines, water-engines, pumps, mills, clocks, watches, dials, telescopes, cranes, jacks, the organ, harpsichord, and every other

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kind of instrument, machine, or engine how ever complicated, or for what ever purposes they are appointed.

IN teaching philosophy as a science, it is necessary to begin with the most simple and known properties of bodies; and thence to proceed, by inferring one truth from another 'till we arrive at the most abstruse parts; always using experiments where the nature of the thing will admit of it, except that which is asserted be sufficiently plain without. And altho' the experiments afford the highest degree of entertainment to the rational mind; yet so much the more instruction will they convey, as this regular process is more attended to and better imprinted on the memory.

LECTURE

LECTURE I.

Of the general Properties of Matter.

THIS Lecture is intended to explain the general properties of matter, the different kinds of attraction, and from thence to deduce the principles of several useful arts. We have four rules whereby we should be guided in our philosophical enquiries, the first is

That more causes for natural effects are not to be admitted than are both true, and sufficient to explain the phenomena.

THIS agrees with reason, and revelation; for it is certain that God has made nothing in vain; which would evidently be the case, if two causes were admitted where one would serve.

THE second is, *That for natural effects of the same kind, the same causes are to be assigned as far as can be done.*

THAT is, we are to assign the same cause for the falling

falling of stones in America, Africa, &c. as in Europe; the same cause for respiration in man and beast; and that light in all kinds of bodies is produced by the very same cause.

THE third rule is, *That the qualities of natural bodies, which cannot be increased or diminished, and agree to all bodies on which experiments can be made, are to be reckoned, as the qualities of all bodies whatsoever.*

THUS, because extension, solidity, divisibility, &c. are found in all bodies that we know, we may justly conclude that they belong to all bodies whatsoever

THE fourth rule is, *That in experimental philosophy, propositions collected from the phænomena, by induction, are to be deemed, notwithstanding contrary hypotheses, either exactly or very nearly true, till other phænomena occur, by which they may be rendered either more accurate, or liable to exception.*

IF according to these rules we take a survey of the Material Creation, and strictly examine the
nature

nature of different bodies, we shall find reason to conclude, that they all consist of the same sort of matter or substance; and that all the difference we observe among them, arises wholly from the various connections, adhesion, and different modifications of the same original particles of matter.

ALL bodies whatever are found to have the following common properties viz.

<i>Extension,</i>	<i>Mobility,</i>
<i>Solidity,</i>	<i>Vis inertiae</i>
<i>Divisibility,</i>	<i>Attraction, and Repulsion.</i>

EXTENSION, is a property which belongs to all matter in general; for it is certain no body can exist, but it must take up some part of space.

SOLIDITY, is that property which a body hath of excluding all others, from the place it possesses.

DIVISIBILITY, is a property whereby bodies are capable of having their parts separated *ad infinitum*. That it exceeds all bounds, is a mathematical

thematical truth, and may be demonstrated different ways, *as shewn in the lecture.*

MOBILITY, is that property which bodies have of being moveable or changing their places.

THE VIS INERTIÆ, or inactivity of matter, is that property whereby they resist the action of other bodies, tending to generate or destroy motion in them.

ATTRACTION, is a property whereby bodies mutually tend towards each other; if the bodies be of unequal magnitude, in the greater, it is called attraction, and in the lesser, gravitation.

REPULSION, seems to be a property belonging to the smallest particles of matter; thus we see the particles of water, separated by the action of fire, repel each other; and the particles of any kind of hard matter, being set at liberty by some chymical process, constitute a perfect elastic air.

ATTRACTION and **REPULSION** seem to be one
and

and the same power, acting differently in different circumstances: but what this power is, none have yet been able to determine, it seems not to be an essential property of matter, but rather a constant impression of divine power.

THE attraction of gravitation takes place only in large bodies such as the sun, earth, and planets, and is a property whereby all smaller bodies within the sphere of their attraction, tend towards their centres. The attracting effluvia or energy is found to decrease as the squares of the distances increase; that is, if a body at the distance of 10,000 miles from the earth tend towards it with a certain force; at the distance of 20,000 miles, it would tend towards it with only one fourth part of that force; at the distance of 30,000, with only one ninth part thereof &c. *as is more fully shewn in the experiments.*

The planets are all retained in their orbits by the attraction of the sun; and by their motions, the above law is fully confirmed; for as the square of the distance of venus from the sun is to the distance that mercury falls from a tangent
to

to his orbit in one hour; so is the square of the distance of mercury from the sun, to the distance that venus falls from a tangent to her orbit, in the same time: *and so of the rest.*

THERE are four different kinds of attraction viz. attraction of cohesion, the attraction of electricity, the attraction of magnetism, and the attraction of gravitation.

THE attraction of cohesion is peculiar to the original particles of matter, and it is mutual between them, or they are attracted and attract each other. This power seems to act only in contact, or at imperceptible distances in all solid bodies. The existence of this power is proved by two leaden balls, having their surfaces pared very clean, and pressed together with a gentle twist, after which they will require 40, 60, or 100 pounds weight to pull them asunder, according as more or less of the surfaces are in contact; for this power seems to act nearly in proportion to the quantities of contiguous surfaces. This is the natural cement by which the parts of solid bodies are bound together, and by which they are kept from crumbling
to

to their original dust. Hard bodies, which cannot by pressure be brought into intimate contact, like the leaden balls, require some kind of matter to be put between them, in order to make them cohere; so if flint, glass, &c. reduced to impalpable powder, and mixed with some viscid fluid, be applied between two bodies, whose surfaces are clean, when dry, it will make them cohere very firmly. Hence, we see the reason that in polished surfaces, a little damp, or the moist which is constantly adhering to them, is sufficient to make them cohere; if a little oil or tallow be used, the cohesion is much stronger, *as is shewn by experiment.*

FROM this principle we have also the nature of foldering, gluing, foliating glass, silvering and gilding metals, *as explained in the lecture.*

THE attraction of cohesion is different between the particles of different bodies; thus, water put into clean glass, china, &c. is seen to rise all round by the side of the vessel; but if quicksilver be used it will stand lowest at the sides; from whence it appears, that the power of attraction is greater between the glass and water, than among the particles
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of water themselves; and that it is greater among the particles of quicksilver, than between the glasses and quicksilver. In this simple cause, divine wisdom is abundantly manifest; for, by it we have numbers of the most extraordinary effects produced.

It is owing to this, that water rises above the common level in the capillary tube; also the action of the capillary syphon, and filtre, depends on the same principle; for the capillary syphon, being a small bended tube of glass, by attraction raises water up one leg, carries it over the bended part, and down the other, where it falls, by its own weight, drop by drop. The filtre being made of yarn, cloth, felt, &c. the filaments act like so many syphons, and carry a fluid off in the same manner, but much faster. From hence we have the reason of fluids rising in heaps of sand, ashes, sugar, &c. of tallow rising in the wicks of candles; of water being drawn up by the sponge; of ink rising in the pen and also of its being drawn out again in writing. From hence we also account for the rising of sap in trees and plants: for upon proper examination it is found that the bodies of trees are composed of an infinite number of capillary tubes, of
different

different magnitudes; the largest seem by various experiments, to be appointed for the circulation of air; and the smaller for attracting the juices of the earth, and raising them to the top and utmost parts of the branches; for it may be observed that the smaller the bore of the tube, the higher a fluid will rise, *as is shewn in the experiment.*

FROM hence we have also the cause of several chymical processes.

FOR if a solid and fluid be put together, provided the power of attraction between the particles of the fluid and the particles of the solid be stronger than between the particles of the solid themselves, every particle of the fluid will then attract a particle of the solid, or so many as it can sustain, and then, the whole menstruum being saturated therewith the solution will cease; as is evident by putting silver, copper, brass, iron, &c. in aquafortis or spirit of nitre; by putting salt or sugar in water; and by water itself being dissolved and diffused thro' every part of the atmosphere, by the strong attraction of the particles of air.

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ANY matter, thus dissolved and suspended, is *precipitated* by the very same cause; for, if to any kind of solution, some other body be added, so that there be a stronger attraction between the new added matter and the menstruum, than between the menstruum and the dissolved body, the new matter will then take place of the old, and let it fall to the bottom.

FERMENTATION depends upon the same power; for if two fluids be put together, provided there be a different power of attraction between their particles, they will thereby be thrown into a strong agitation and commotion amongst themselves, and will be so incorporated with each other, that they will seem to have changed their properties and acquired new ones.

FROM this difference of the degrees of attraction between different bodies, we have perhaps the most rational way of accounting for heat, explosions, earthquakes, vulcano's, &c.

IF aqua-fortis be poured upon iron-filings, a very considerable degree of heat is produced.

Also

ALso if three parts of nitre, two of salt of tartar, and one of sulphur, be pounded and mixed together (which mixture is called the *pulvis fulminans*) and a small quantity of it heated upon a plate, as soon as it begins to melt, and the particles of the different bodies come in contact, they are attracted with so much force as to cause a sudden explosion.

ALso, if equal parts of sulphur and iron-filings be made into a paste with water, and put under ground, they will, in eight or ten hours time, take fire, and blow up the ground about them, venting flames and smoke like a vulcano; and as it is well known that the earth abounds with great quantities of sulphur, iron ore, &c. it is probable these may be brought together, either by subterraneous waters, or other causes unknown to us, and by the violence of their fermentation, at length break forth in flames, as in burning mountains; or when confined deep in the bowels of the earth, if the compactness of the superincumbent mass refuses to give way for an eruption, the effort for enlargement is then made on that quarter, which, by caverns, or the more yielding and loose contexture of its parts, affords the least resistance; hence may arise that wandering

convulsive motion, which is denominated an earthquake.

THE attraction of *magnetism* is peculiar to the loadstone and iron, as there is no other body but iron that it can be communicated to.

EVERY loadstone has two poles, one called the north, and the other the south pole, one of these poles attracts, and the other repels iron.

THIS virtue may be communicated to iron different ways, and thereby artificial magnets may be made to answer all the ends of a natural one.

IF we take four or five steel bars, six inches long, half an inch broad, and about an eighth of an inch thick, well polished and hardened, if they be laid end to end and the magnet drawn over them several times, they will become strongly impregnated with the virtue: these properly fitted up in a case will make a good artificial magnet; but perhaps it may be better in some cases to have the bars bent in a particular manner, *as is shown in the experiment.*

THIS

THIS virtue may also be communicated to a piece of polished steel, by placing it in the magnetic meridian, and rubbing it always one way with a burnisher.

IRON bars, by standing long in one position, acquire the magnetic virtue.

IF a magnet be made red hot, or become rusty, it loses all its virtue.

IT is generally supposed that the effluvia, coming out at one pole, return in curves of various directions, and enter in at the other; and indeed we have several experiments which countenance such an hypothesis.

IF a needle be touched and suspended upon a point, it will stand in a direction nearly north and south, and will also be disposed to dip with the north end about 74° below the horizon.

IF a needle be touched with the south pole of the magnet, that end towards which it is drawn, will stand toward the north; and that end toward,

which the north pole is drawn, will stand toward the south: but if the same pole be drawn the contrary way, it will stand in the contrary direction.

It may be observed that the needle in England at this time does not stand truly north and south, but varies about two points from the north toward the west. In 1580 it stood one point to the east, in 1657 it stood in the meridian or pointed truly north, so that it seems to be constantly moving westward: in different parts of the world the direction is very different; some places it has east variation, some places west variation, at others no variation at all.

WE have not yet had any satisfactory way of accounting either for the cause of the needle's pointing toward the north, or of its variation.

LECTURE

LECTURE II.

Of Pneumatics.

PNEUMATICS is that part of philosophy which treats of the nature and properties of the air.

THE particles of air are extremely small, so that they evade the sight, though assisted with the best glasses; it is most likely that these particles are round, and that a repelling power takes place between them, for the air is found to be an elastic fluid.

THE whole body of air in which we breathe, and which surrounds the globe of the earth is called the atmosphere.

THE air, being elastic, is at every different altitude of a different density; that is, it is most dense upon the surface of the earth, and the higher we ascend, it becomes more rare or thin; except that which is near the earth be sometimes rarified by the heat reflected from its surface.

THE altitude of the atmosphere is not exactly known; it extends about 45 miles above the earth's surface before it be too thin to refract a ray of light; if it were every where of the same density with that near the earth, its altitude would be about five miles and a quarter.

THAT the air is a body, is evident by its excluding other bodies from the place it possesses, for if a glass be inverted and sunk in water, the water will not rise in it, as is evident by a lighted candle continuing to burn in it, though under water: the diving bell depends upon this property of the air; for if a large vessel be made heavy enough to sink mouth downward in water, a person may descend in it to a considerable depth, and the water will be kept from rising by the spring of the air; yet the air being elastic, and therefore capable of being compressed, as the bell descends the water will gradually rise; and when it comes to the depth of 33 feet, half its capacity will be filled with water; but it may be kept from rising, or driven out after it is risen, by sending fresh air down in casks which may be taken in at the bottom of the bell.

bell, while that corrupted by breathing may be discharged at the top by a cock for that purpose.

As the air is a body, it has also weight, or gravitates towards the earth like other bodies, in proportion to its quantity of matter.

The weight of the air is evident from a number of experiments.

1. If the hand be laid upon an open topt receiver, and the air pumped from under it, the weight of the external air will be felt upon the back of the hand, and will press it close down to the receiver.

2. If a glass bubble, containing a wine quart be emptied of its air, and then nicely balanced, as soon as the air re-enters, it will preponderate, and will be about 17 grains heavier than when empty.

3. If two brass hemispheres, put together by wet leather, be exhausted, and the air shut out by a cock, they will require a force of about 15 pounds to every square inch to pull them asunder.

If

4. IF a glass bubble, with its neck immersed in water, be exhausted of its air, when the air re-enters, its weight will press upon the surface of the water, and force it up into the bubble.

5. LET a tall receiver be set upon a moveable plate, to which is screwed a pipe with a cock, and exhaust it, then placing the end of the pipe in water, and opening the cock, the pressure of the external air will be seen forcing the water up the receiver with a great velocity.

6. TAKE a stick of oak, hazel, &c. with a hoop round one end of it to hold quicksilver, and with wet leathers fix it in the top of an open receiver, so as to be air-tight, when the receiver is exhausted, the weight of the air pressing upon the mercury in the hoop, will force it through the pores of the wood.

7. IF a bladder be fast tied over the top of an open receiver, as soon as the air is sufficiently rarified below; the weight of the column above, will break the bladder with a considerable report.

IF

8. IF a piece of hazel, having its ends cut very smooth, be fixed in the neck of an open receiver, and the lower end immersed in water, upon exhausting, the outward air, by its weight will rush thro' the pores of the wood, and rise thro' the water in fine streams.

9. IF a square glass bottle be exhausted, it will be broke into small pieces, by the pressure of the circumambient air.

10. A PIECE of plain glass laid over an open receiver, will be broke in the same manner.

11. IF a barometer be placed under a tall receiver, as the air is exhausted, the mercury will fall; when the air re-enters, it will rise again: from hence it is evident that the mercury is supported in the tube, by the weight of the air; and therefore, in fine dry weather, when the atmosphere is heaviest, it must stand highest; on the contrary, in rainy weather, when it is lightest, the quicksilver must be lowest.

FROM this experiment it is found that the air
will

will support a column of mercury to the altitude of $29\frac{1}{2}$ inches, at a mean; the diameter of the tube makes no difference, the reason of which will appear evident when we come to the laws of *hydrostatics*; and as the weight of a column of mercury, of any given diameter and altitude, is known, the weight of a column of air, of the same diameter, is also known, and is at a mean about 14 lb. upon every square inch; and upon every square foot 18 cwt. or near one ton: and if we suppose the surface of a middle-sized man to be 15 feet, it will follow that he will sustain a pressure of $13\frac{1}{2}$ tons; which, were it not balanced by the spring of internal air, could not be supported.

BUT the particles of air being extremely small, enter into every part of our bodies, and by their elasticity balance the pressure of the ambient atmosphere.

12. THIS is evident by placing the hand upon an open receiver, for as soon as the pressure is destroyed, the air in the flesh, by its spring, will swell out the skin.

14. A

13. A SMALL receiver, placed over the hole in the pump plate, as soon as the air is exhausted, will be strongly pressed down by the column which is over it.

14. It is supposed by many, that this and other like effects, are caused by *suction*, or by something within the glass drawing it down thro' the hole of the pump plate; but this is false, *as we shew by experiment*; for if a small glass be placed on one side of the hole, and covered with a larger, then while the larger is exhausting, the small one will be loose; but when the air is let in again, the large one will be set at liberty and the small one, by the weight of the air, will be fixed.

THERE is no effect in nature produced by any cause that can be called *suction*; except that appellation be falsely applied to the *attraction of cohesion*.

15. SMOAKING of tobacco and sucking the breast are performed by the pressure of the air: for a vacuum being made in the mouth by drawing back, or bending down the tongue, the air by its weight rushes thro' the pipe; and by pressing
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upon

upon the breast forces the milk into the child's mouth.

THE elasticity of the air will appear from the following experiments;

16. IF a bladder, nearly emptied of its air, be fast tied, and placed under the receiver, as the air is exhausted, the bladder, by the expansion of the included air, will swell out, and at length appear full blown.

17. IF a glass bubble, having its neck placed in water, be covered with a receiver, as the air is exhausted, that in the glass by its spring will make its escape, and will be seen rising thro' the water in large bubbles.

18. IF an egg, having a hole in its little end, be placed under the receiver, upon exhausting, the air bubble contained in the great end, will, by its spring, drive out the contents.

19. IF an egg be sunk in a glass of clear water, upon exhausting, the air will be seen to rise from every

every part of the shell, in innumerable fine streams; but most copiously from the great end.

20. TAKE a bladder containing a little air, put it in a proper vessel, and lay a weight upon it, cover the whole with a receiver, then work the pump, and the spring of the air will be seen to raise the weight.

21. IF a shrivelled apple be placed under the receiver, and the air exhausted, the air contained in the apple will expand itself, and cause the apple to appear plump and fair.

22. IF a piece of dry wood be sunk in water, and covered with a recipient, upon exhausting, the air contained in the pores of the wood, will expand itself, and rise thro' the water in great quantities.

23. THE experiment will succeed with green wood, leaves, &c. but the quantity of air thrown out will not be so great: from this it is evident that there are air vessels in vegetables.

24. IF a piece of gold &c. be put in water
under

under a receiver, on exhausting, the air contained in the pores of the surface of the metal, will expand itself and appear all over the surface.

25. If a small bladder, with a little air and a weight in it, be fast tied and sunk in water, upon exhausting, the air contained in the bladder will expand itself, and cause the bladder and weight to swim.

26. Also if a cork be just made to sink, by fixing lead to it, it will be brought to the top, by the air bubbles adhering to its surface.

27. If a glass of clear water be placed under the receiver, upon exhausting, the air will expand itself, and may be seen to rise from every part of the water in fine streams.

28. If we use fresh beer instead of water, the air bubbles will not burst, because the beer is more viscid, but will rise in a fine frothy head.

29. Join a tall receiver, exhausted of its air, to the top of a vessel about half filled with water,
a pipe

a pipe going down near the bottom of the vessel, open the cock and the spring of the air acting upon the surface of the water, will cause it to rise in the receiver with a great velocity, and will make a beautiful fountain.

30. TAKE a long glass tube, open at both ends, fix it with cement, in the neck of a phial, about half filled with mercury, so that the lower end may reach near the bottom of the phial; place the whole under a receiver, and upon exhausting, the spring of the air upon the surface of the mercury, will cause it to rise in the tube just as fast as the mercury rises in the pump-gauge; which shews that the spring is exactly equal to its pressure.

31. If a phial of hot water be placed under the receiver, as soon as the pressure of the air is taken off its surface, it will begin to boil with great rapidity: a much less degree of heat being sufficient to cause the phenomenon in a vacuum, than when under the compression of the atmosphere.

32. If a fish be put into a jar of water, and covered with a recipient, as soon as the pressure of the
C atmosphere

atmosphere is removed, the air contained in the air-bladder will expand itself, and cause the fish to swim: but it will not very readily die.

33. If we put a mouse, rat, cat, &c. under the receiver and exhaust the air, the animal will immediately die. From whence it appears that it is absolutely necessary for supporting the lives of these and all other kinds of large animals.

34. BUT *insects, reptiles, &c.* will not die *in vacuo*.

35. AIR is necessary for the support of fire and flame; for burning coals, or a lighted candle will instantly go out *in vacuo*.

36. EXPLOSIONS are caused by the resistance and concussion of the air, for gunpowder will not flash *in vacuo*.

37. IT is owing to the resistance of the air that light and heavy bodies do not fall equally fast, for *a guinea and a feather* will fall to the bottom of a tall receiver, when exhausted, in the same time.

38. THAT

38. THAT the air is necessary for the support of vapours is evident, for as soon as the receiver begins to be exhausted, the vapours may be seen descending like a mist.

39. IN order to prove that water is raised by the attraction of the air, *as asserted in the first lecture*, take two tea-saucers, pour in water till they be exactly of the same weight, place one under an exhausted receiver, and the other in the open air, after they have stood a few hours, weigh them again, and that which was exposed to the air will be found much lighter; tho' the experiment be made in the coldest weather.

40. THAT sound is conveyed from place to place by the medium of air, will appear evident by the following experiments.

IF we place a bell upon the plate of the pump, and cover it with a receiver, if the bell be rung, the sound will be much weaker than when in the open air, tho' the receiver be not exhausted; if the receiver be well exhausted, the sound will not be audible, except very near the pump; but as a

perfect vacuum cannot be made, the small quantity of remaining air, will faintly convey the pulses to the glass, which by a tremulous motion, will convey them to the outward air: from this, it appears that sound moves thro' the air, without the air being carried with it from place to place.

IF an elastic body be struck, or otherwise put in motion, it will continue to vibrate backward and forward for some time; the particles of air which are near it, will by its quick vibrations, be put into the same tremulous motion with itself, and they, in their approach to those which lie next them, will communicate it to them also; and so on to a considerable distance, depending on the intensity of the stroke, and the nature of the sonorous body.

THESE aerial pulses or waves are propagated from the sounding body, in concentric spheres or shells, decreasing in density as the squares of the distances increase; hence a person at the distance of one mile from a sonorous body, will hear the sound four times as loud as he would do at the distance of two miles, &c.

THE

THE velocity of sound, according to the most accurate experiments, is at the rate of 1142 feet per second ; all sounds whether strong or weak move with the same degree of velocity, and nearly as fast when they move against the wind, as when they move with it ; but they may be heard much further in the direction that the wind blows, than in the contrary.

THE velocity of sound increases with the elasticity of the air, and is therefore something greater in summer than in winter ; yet sounds are more audible in winter than in summer, because the air is more dense ;* for the same reason sound is much stronger in a valley than upon the top of a mountain, where the air is less condensed by the weight of the incumbent atmosphere.

As sound is propagated from the sonorous body in all directions, if it happens to strike against rocks, buildings, woods, &c. the pulses will be re-

C 3

flected

* It seems to be owing to the density of the air, arising from the coldness of the water, that sound may be heard further over a lake than over a valley.

flected back, and the sound repeated, which is called an *echo*.

IF a musical chord be put in motion, all its vibrations, whether great or small, will be performed in the same time; and therefore the chord, however struck, will always produce the same note.

IN order to produce different notes from the same string, either the length, or the tension of the string must be altered.

IF we take eight musical strings of the same thickness, and stretch them with equal weights, and if we make their lengths as, 100. 88,8. 80. 75. 66,6. 60. 53,3. 50. they will sound the notes of the *diatonic scale*, viz. C. D, E. F. G. A. B. C. yet the sounds of the higher notes would be more agreeable, if the strings were smaller and longer, and their tension less.

IF two strings perform their vibrations in the same time, the note or tone produced is called an *unison*, and is the most perfect concord. If one string performs two vibrations while the other performs

performs one, they will sound an *octave*, which is the next perfect. If one performs three for the other two; they will sound a *fifth*. If one four, for the other three; a *fourth*. If one five, for the other four; a *third greater*.

If two musical chords, placed near each other, be tuned unison, and one made to vibrate, the other will vibrate also, if the string which is struck be an octave above the other, the two extremes of the other will sound unison with it, while the middle point remains at rest: in the same circumstances the same effect is produced by all kinds of sonorous bodies; for the vibrations of the air when put into a tremulous motion by the sounding body, agree exactly with those which may be produced by the body at rest, and the vibrations of this resting body, which in some faint degree are caused by the first impulses of the vibrating air, are by its corresponding motion, continually encreased.

That the air may be condensed is evident from the following experiments.

41. LET a strong receiver, with a full blown

C 4

bladder

bladder under it, be firmly screwed down upon the plate of the pump, then with a syringe, or with the pump, if it be of *Smeaton's* construction, force in a quantity of air, and the bladder will begin to contract or shrivel up: whence it is evident that the air in the bladder is condensed or squeezed into a less space than it possessed before: and as soon as the cock is opened and the pressure removed, it will again expand itself and fill the bladder.

THE condensation ought not to be too great, when the receiver is of glass, lest it should burst, which might be attended with bad consequences.

IF only a double atmosphere be forced into a receiver of five inches diameter, and eight inches high, there will be a force of 1680 lb. acting against its inner surface; if a treble atmosphere, 3360.

42. IF a glass bubble, with its neck immersed in quicksilver, be placed under the receiver, and a double atmosphere forced in, half the capacity of the bubble will be filled with quicksilver, and the air which in its natural state, filled the whole capacity, will be compressed in one half thereof.

43. IF

43. If air be condensed upon the surface of water in a strong vessel it will cause it to spout thro' the tube of communication with a surprising velocity, and will make a beautiful fountain, or jet d' eau.

THERE is a kind of air frequently found in the bottoms of deep pits, mines, &c. commonly called the choke damp, it is considerably heavier than common air, extinguishes candles, and is instant death to animals.

44. THIS kind of air may be produced by pouring aqua-fortis, or oil of vitriol, diluted with water, upon pounded chalk; also a noxious air, something like this, may be made by letting the air into an exhausted receiver thro' a charcoal fire, or thro' a hot brazen tube.

45. AN inflammable air is made by exhausting a receiver, and letting the air in again thro' burning oil of turpentine, for if a candle be put down into this air, it will take fire and burn: it is also noxious to the highest degree, for an animal dies in it in an instant.

AIR

AIR is also made noxious by the putrefaction of vegetables or animal substances; by the burning of candles; by animal respiration; by the calcination of metals; by the effervescence of iron-filings and brimstone; by the effluvia of white paint; by exhalations from putrid marshes; &c. from hence it is evident that great quantities of air are daily corrupted, and without some remedy, the whole atmosphere would at length become pestilential.

How air made noxious is again purified, or rendered fit for breathing, has long been a subject of enquiry; but it appears by some late experiments, made by Dr. Priestly, that *water* and *growing vegetables* tend to restore it to a state of purity, which discovery may be of the greatest importance to mankind.

THE air is an elastic fluid capable of being expanded by heat and contracted by cold; hence if any part be heated it will be rendered specifically lighter than the adjoining air, and will therefore rise into the higher parts of the atmosphere, and the neighbouring air, by its weight, will rush into its place and thereby a stream of air or wind will be

be produced; thus we find the air rushing thro' the key-hole, chinks, crevices, &c. into a close room where a great fire is made: and the rarefaction made by the heat of the sun, is the cause of all the *regular* winds, whether general or periodical; for the air to which the sun is vertical, is rendered hotter than in any other region, and is therefore constantly rising into the upper parts of the atmosphere, while the heavier air from all sides is moving in to supply its place; but as the motion of the sun is toward the west, the easterly wind prevails. Under the equinoctial it blows nearly from the east point; but as the distance increases it varies more and more on both sides 'till about the 30th degree of latitude, where, on the north side it blows from the N. E. and on the south side from the S. E. but this is to be understood only of open seas; for the direction is altered by hot sands, mountains, &c. and the wind generally blows towards the land: hence we have the reason of the periodical trade winds or monsoons which blow six months in one direction, and six months in the contrary; *as is fully explained in the lecture.*

LECTURE

LECTURE III.

Of Hydrostatics.

HYDROSTATICS is that part of philosophy which treats of the *properties, pressure, and laws* of fluids.

A FLUID is generally defined to be a body, whose parts move freely among themselves, and therefore yield to the least partial pressure. From whence it is supposed that the particles of a fluid are small, round, smooth. and hard. That fluids are porous is evident from their bulk not being increased by the addition of as much salt &c. as they can dissolve.

All fluids, except air, are incompressible. That is, they cannot be forced or squeezed into a smaller space than what they naturally possess. This is evident by filling a globe of copper with water, and pressing it with a icrew, for the water issues thro' the pores of the metal and stands like dew all over its surface.

HENCE

HENCE it follows, that the ocean and other deep waters, must be every where of the same density, that is, they will not be more dense at the bottom than at the top. *Yet the pressure will be in proportion to the depth,* as is easy to conceive, by supposing a fluid composed of a number of thin plates, piled up one upon another, for it is evident, that the higher the column, the greater will be the pressure upon the lowest.

THIS is proved by putting the open end of a barometer tube, into a wider tube almost fill'd with water; for as the small tube descends the water is seen to rise in it, in proportion to the depth, tho' equally resisted by the spring of the internal air.

THE pressure of fluids at the same depth *is every way equal*, as upwards, downwards, and sideways, and is always *in proportion to the perpendicular altitude*, without any regard to the quantity. That is, a sluice will be equally as much pressed in the side of a pond four yards in diameter, as it would be if the said pond was four miles in diameter.

IF a piece of flat lead be holden close to the
bottom

bottom of an open cylinder covered with leather, and placed more than twelve times its thickness below the surface, it will be sustained by the upward pressure of the water.

LET two round boards, be put together with leather, after the manner of bellows, in the middle of the upper board fix a long tube, thro' which pour water into the bellows, and the higher board will be raised by the upward pressure, tho' a considerable weight be laid upon it.

LET the upper board of these bellows be fixed, and to the bottom fasten a wire, which coming thro' the tube, may be hooked to the end of a scale-beam; then put weights into the scale at the opposite end, till the water be seen rising above the upper board, now supposing the weight sufficient for that purpose be two pounds, then must the bottom of the bellows necessarily sustain a pressure of that weight, for the two scales are just balanced. If to these weights another pound be added, the water will rise in the tube, till its pressure at the bottom, being encreased to three pounds, restore the equilibrium. In the same manner, for every additional

additional pound thrown into the scale, the water will rise an equal space in the tube, and preserve, by its pressure, an equal counterpoise.

FOR example, let us suppose that every pound put into the scale raises the water one inch in the tube; then if it be raised 20 inches, the bottom must be pressed with a force of 20 pounds, altho' the absolute weight of the water be not more than 2 pounds.

THIS very singular effect which is generally called the *hydrostatic paradox*, is thus accounted for: the upward pressure at the same depth is equal to the downward pressure, and therefore the fixed part is pressed upwards with a force equal to the weight of a column of water of the same altitude with that in the tube, and of a diameter equal to the said fixed part, which *part* re-acts upon the water and causes it to press upon the bottom with a force equal to the weight of a column of the beforementioned altitude, encreased by the depth of the bellows, of a diameter equal to that of the bottom.

TAKE an open glass cylinder, over one end of which

which, let a bladder be tied flaccid; fill the cylinder, to any height at pleasure, with water, and by its weight the bladder will be made convex on the low side, put the cylinder gradually into a large vessel of water, and while the surface of that in the cylinder is higher than that in the vessel, the bladder will continue to be bulged downward; as soon as their surfaces become level, or of the same height, the bladder will be flaccid; if the cylinder be sunk deeper, the bladder will become convex on the upper side, by the superior upward pressure of the water in the vessel, because its surface is the higher.

LET a small and wide tube be joined together at the bottom, pour water into the wide tube, and it will rise in the small *one* to the same height, but not higher, whence it is evident that the pressure is in proportion to the perpendicular altitude; for were it as the quantities which the tubes contain, the altitude in the small one should be, to the altitude in the wide one, as the square of the diameter of the wide tube, to the square of the diameter of the small *one*,

from

FROM hence we see the reason of conveying water by aqueducts; or why water may be conveyed to any place not higher than the source, tho' a valley intervene, by means of a bended pipe; for it is evident the water will always rise to the level of the spring, whatever the form of the pipe be.

THE pressure of a fluid against the sides or bottom of a vessel, may be computed as follows; *for the bottom*; multiply the depth in inches by .03617 and the product thence arising, by the area of the bottom, in inches; this last product will be the whole pressure upon the bottom in pounds avoirdupoise.

FOR *a side*; multiply the area under water, in inches by .03617, and that again by the depth of the centre of gravity, in inches; the product will be the pressure, in pounds, as before.

THE velocity with which water spouts out at a hole in the bottom or side of a vessel, is equal to that which would be acquired by a heavy body,

D

in

in falling from the surface of the water to the said hole.

A HEAVY body will fall thro' a space of 16.13 feet nearly, the first second, and will thereby acquire a force which would carry it with an uniform motion, over a space of 32.26 feet per second.

THEREFORE if a hole be made in the side of a vessel, or thro' the breast of a dam, at the depth of 16.13 feet below the surface, the water will spout out, with a velocity of 32.26 feet per second.

THE velocity with which water spouts out at holes, made at different depths below the surface, is as the square root of these depths. *As for example:* should it be required to find the velocity, with which a fluid would spout thro' a hole 9 feet below the surface, it would be, as 4 (the square root of 16) is to 3, (the square root of 9) so is 32 (the velocity at 16 feet below the surface) to 24 feet, the velocity per second, required.

OR if the square root of the depth in feet be multiplied by 8, it will give the velocity in feet, per second.

THE

THE following Table (which may be of service to those who are concerned in water-works) shews the velocity per second with which water spouts from holes made in the side of a vessel, from one to sixty feet below the surface.

Depth in Feet.	Velocity per second in Feet.	Depth in Feet.	Velocity per second in Feet.
1	8.	17	32.96
2	11.28	18	34.
3	13.84	19	34.88
4	16.	20	35.76
5	17.84	21	36.64
6	19.6	22	37.52
7	21.12	23	38.4
8	22.64	24	39.2
		25	40.
9	24.		
10	25.28	30	43.84
11	26.64	35	47.04
12	27.76	40	50.56
13	28.88	45	53.68
14	29.92	50	56.56
15	30.96	55	59.2
16	32.	60	62.

D 2

N. B. I.

N. B. In this table I have taken the velocity at 16 feet, to be 32 feet per second, not regarding the decimal.

It is necessary that there be a free passage to the hole from which the fluid spouts, otherwise the velocity will be greatly retarded.

THE quantity of water discharged at any depth below the surface, while the aperture remains the same, will be as the velocity at that depth. *As for example:* Should 8 pints be discharged thro' a hole, one foot below the surface, in a certain time; then an equal hole, made 2 feet below the surface, would discharge 11.28 pints in the same time; and so on as in the table.

SPOUTING fluids, when applied to wheels, should strike them in the direction of a tangent; or they should flow in such a manner, were the float-boards or ladles away, as to pass by the wheel, only just touching its circumference. If this be not the case a considerable part of the force will be destroyed, and the velocity proportionably retarded

retarded; which perhaps may be necessary where a slow motion is required.

By the table we see what different degrees of velocity will be given to a wheel, by water flowing thro' sluices, at different depths below the surface.

Example: If when the depth is 4 feet the wheel makes 16 revolutions in a certain time; then when the depth is 9 feet it will make 24 revolutions in the same time, &c.

Of Solids immersed in Fluids.

If a solid be immersed in a fluid, it loses just so much of its weight, as is equal to the weight of its equal bulk of the fluid. Take a cylindric bucket and a solid cylinder of brass &c. which will exactly fill it; let the bucket be suspended from the end of a scale beam, and the cylinder from the bottom of the bucket, balance them by putting weights into the opposite scale; then place the cylinder in a jar of water, and the equilibrium will be destroyed; pour water into the bucket till it be full and it will be restored again. *Whence it is evident that the cylinder is resisted by the weight of its bulk of water.*

FROM this it appears that if a body be lighter than water, bulk for bulk, it cannot descend, because it is resisted by the weight of its equal bulk of water: If it be heavier it will lose so much of its weight, as is equal to its bulk of water, and descend with the rest; if it be the same weight with water, bulk for bulk, it will remain at rest in any part of the water, *all which is shewn by small glass images, whose specific gravities may be increased at pleasure.*

Relative or specific gravity is the gravity or weight of one body compared with the weight of another, of equal magnitude.

IF a cubic inch of gold be twice the weight of a cubic inch of copper, then are their specific gravities said to be as two to one.

THE specific gravity of any kind of matter is easily found by the *hydrostatic-balance*; for if we suspend the body, whose specific gravity we would know, from the bottom of a scale, by a fine thread, and then balance it exactly, first in *air*, and then in *water*; It will be, as the difference
between

between the weight in water and in air, is to the weight in air; so is the specific gravity of water, to the specific gravity of the body required.

HENCE if the weight of the body in air, be divided by what it loses in water, the quotient will shew how many times it is heavier than water.

IN order to find the specific gravities of fluids; let a solid piece of glass be suspended from a scale, as before, and exactly ballanced in the air; if then it be immerfed in different kinds of fluids, the grains put into the scale over it every time, to restore the equilibrium, will express the relative gravities of the fluids.

THE specific gravities of different bodies, found by the above process, are expressed in the following table.

A Table of the specific gravities of different bodies.

		oz.
A cubic Foot of	Pure Gold, - -	19,640
	Standard Gold,	17,150
	Pure Silver, -	11,091
	Standard Silver,	10,000
	Lead, - - -	10,130
	Copper, - - -	9,000
	Brass cast, - -	7,856
	Iron, - - -	7,645
	Tin, - - -	7,551
	Flint Glass, -	2,542
	Slate, - - -	2,750
	Dry Oak, - -	925
	Pit-coal, - - -	1,272
	Ebony, - - -	1,177
	Ivory, - - -	1,862
	Dry Fir, - - -	546
	Mercury, - -	13,610
	Rain Water, -	1,000
	Aqua-fortis, -	1,300
	Spirit of Wine -	840
	Red Wine, - -	993

THE specific gravity of fluids may be found by pouring a little mercury into a bended glass tube open at both ends, and then pouring into each leg a different kind of fluid, and in such quantities that the mercury in each leg may stand to the same altitude, and if the fluids poured in be of different altitudes

altitudes, their specific gravities will be reciprocally as those altitudes.

THE *Hydrometer* is an instrument which is sometimes used for finding the specific gravities of fluids: it consists of a hollow ball of copper, ivory, or glass, with a long stem fixed in one side and a weight screwed to the other; if the weight be so adjusted as to sink the instrument to the middle of the stem when immersed in proof spirit, (which is made by mixing equal parts of pure spirit and water) it will, if immersed in any other kind of spirit, shew whether it be above or below proof; if the instrument sink deeper than the said mark, it is above, but if not so deep, it is below proof.

LECTURE IV.

Of Hydraulics, &c.

THE syphon or crane is a bended tube, which being filled with water and then inverted, the outward leg reaching below the surface of the water to be conveyed through it, the water in the longer leg by its weight will begin to descend, and that in the other by the pressure of the air will be forced after it, provided the altitude of the syphon above the water do not exceed 33 feet.

The phaenomenon of the Tantalus's cup, is owing to a concealed syphon, the highest part whereof reaches near the top of the vessel, one leg reaching below the bottom, and the other communicating with the inside near the bottom; as the cup is filled with water, the syphon will also be filled; or the water will continue to rise in the cup, 'till it run over the bended part of the syphon, when the syphon will begin to run and the cup will be emptied.

INTERMITTING springs are accounted for upon
this

this principle, a syphon being formed in the earth and communicating with some cavity near the bottom; if this receptacle be not supplied with water as fast as the syphon will carry it off, it will then rise, as in the cup, 'till the syphon begin to run, which will continue 'till the cavity be emptied, or 'till the water falls below the orifice of the syphon, and then it will cease.

THE *fountain at command* is a cylindric vessel about four inches wide and five inches high, closed at both ends; in one end are inserted, round the centre five or six small pipes, half an inch long, and one eighth in diameter; in the centre is soldered a tube fourteen or eighteen inches long, and half an inch in diameter, one end of this tube goes near the top of the vessel, and on the other are soldered three claws to stand upon, and which raise the lower orifice of the tube about half an inch above the bottom of a cup, in which it is placed; in which bottom is made a small hole; the vessel being almost filled with water thro' the long tube, and then inverted, it will run out thro' the small pipes into the basin and will rise 'till it touch the lower end of the wide tube, and then the fountain will

will cease to run, because the air is kept from entering thro' the long tube and pressing upon the surface of the water in the vessel; but as the water is constantly running out of the cup thro' the small hole in the bottom, as soon as it falls below the orifice of the long pipe, the fountain will again begin to play.

THE action of the common *pump* depends upon the pressure of the air: a piston, with a valve in it, being made to fit the bore of the pump, is put down near a valve which is fixed below in the barrel; a little water is poured upon it to make it air-tight, and then, when it is lifted up, the column of air upon it is also lifted, and the spring of that below in the pump is weakened, and the water, by the pressure of the air is raised in the barrel, 'till its weight, together with the spring of the internal air balance the outward atmosphere; the stroke being repeated, when the piston is put down, the air above the fixed valve makes its escape thro' the piston's valve; when it is raised the air below is again expanded and the water raised as before, &c. until after a number of strokes the water is raised
above

above the piston and brought up into the cistern, from whence it may run off.

IN constructing a pump of this sort, it is necessary that the valve be not fixed too high, viz. not more than 20 or 24 feet, and in some cases not more than 15 feet above the surface of the water.

FOR altho' the pressure of the atmosphere will raise a column of water to the altitude of 32 or 34 feet provided a perfect *vacuum* be made; yet the velocity with which it rises, at any altitude above 24 feet is too small where any considerable quantity of water is to be raised: at the surface the velocity with which it follows the piston is upwards of 45 feet per second, but decreases to the altitude of 34 feet, where it is nothing.

IF the *wind bore* or sucking pipe be made too small in proportion to the working barrel, so that the water do not rise with a sufficient velocity thro' the valve, to fill the vacuum in the working barrel left by the piston, the pump will then be much harder to work, for whatever the column below the
piston

piston wants of 32 feet, it will be added by the pressure of the atmosphere.

THE velocity with which the piston rises, its altitude above the water, and the diameter of the working barrel, are all to be considered in computing the diameter of the wind bore, or the diameter of the valve, for it is little advantage to have the lower pipe wider than the valve at the top thereof.

THOSE who are not able to adjust the dimensions by theory, should fix the valve near enough the surface of the water, as within 20 feet, for in this there is no disadvantage in working the pump, as many people suppose.

FOR should it be required to raise water 40 feet, the weight of water to be lifted every stroke will be the same, whether the spear be 15 or 30 foot long, tho' in the first case there will be but half the quantity of water upon the piston, that there will be in the second, but as the weight upon the piston at every stroke, is equal to the weight of a column of water of the same diameter with the piston, and of an altitude equal to the distance between the
surface

surface of the water in the well, and the surface of that in the cistern, it can make no difference in what part of the pump the piston plays, provided it be near enough the bottom: for tho' the water be forced up the lowerpart of the pump by the weight of the atmosphere, yet the said part is first exhausted of its air by the piston, which is constantly pressed by the column of air above it with a force equal to the weight of the column of water below.

FROM hence it is evident, that while the working barrel remains the same, there can be no advantage in contracting either the lower or upper part of the pump: for it has been already proved, *that, while the bottom or piston remains the same, the pressure is in proportion to the altitude.*

IN the *forcing pump*, the piston is solid, or without a valve, a pipe with a valve in it is fixed in the side of the pump, just above the fixed valve; so that when the piston is pushed down the water is forced out at the side pipe, and is hindered from returning by the valve, the side pipe may be of any length
required

required, and by it the water may be forced to the tops of buildings, &c.

IN the *lifting pump*, the spear goes in at the bottom, is wrought by means of a frame, and can therefore only be used in deep water.

THE *draining pump* is made square with a valve in the bottom; it is mostly wrought in an inclined position, the piston is made in the form of a hopper, the edges are fixed with cords to the spear, when it is lifted up, the water presses it close to the pump, but when it is pushed down, the sides bend in and give way for the water, sand, gravel, &c. to rise.

THE *screw of Archimedes* is a tube open at both ends, coiled round a cylinder; when it is to be used it is placed in an inclined position, with the lower end in water, and upon turning it round the water is brought out at the top.

THE *centrifugal pump* raises water by a centrifugal force combined with the pressure of the atmosphere, it cannot raise water higher than 30 f. et,
because

because it has no piston, and the velocity with which it rises at a greater altitude, by the pressure of the air, is too slow for this pump. The quantity of water raised by it is very considerable, yet it is not found to answer so well as at first expected.

NEWSHAM's *fire-engine*, consists of two forcing pumps which alternately force the water into a strong air vessel, in the top of which a pipe is fixed and extends near the bottom: when the water is risen in the vessel to the bottom of the pipe the air cannot make its escape, but as the water rises it will be compressed in the crown of the vessel, and by its spring will forcibly act upon the surface of the water, and force it to spout thro' the pipe with an exceeding great velocity, and by means of a proper contrivance at the top, may be thrown in any direction at pleasure.

THE *cylindric mill* which grinds without a wheel and with a small stream of water, is made of a long upright tube, open at the top to receive the water; at the bottom it has two cross arms (some have added four or six but it is no advantage) when the cylinder and arms are filled with water, the

E

arms

arms will be pressed outward on every side with a force which will be as the height of the cylinder; suppose it be 14lb upon every square inch, then if in each arm, and on opposite sides a hole be made of four inches square, there will be sixteen stones acting on each arm, or 32 in the whole, to turn the mill.

THE *fire-engine* consists of a large beam, cylinder, boiler, &c. in the cylinder which stands upright, a piston is suspended from one end of the *beam*, and to the other, are fixed the pump rods. The cylinder and boiler are made to communicate by means of a pipe, in which is placed a plate called the *regulator*. The boiler is filled with water to a certain depth, which by fire is converted into a vastly elastic steam, the strength of which is known by its lifting a valve at the top of the boiler, called the *steam clack*; when the regulator is open the steam enters into the cylinder and drives out the air thro' a small hole, covered with a valve called the *snifting clack*. When the cylinder is filled with steam, the regulator is shut, and the *injection-cock* is opened, by which a jet of cold water is let into the cylinder, from a cistern fixed
above

above; this jet condenses the steam, and makes a sufficient *vacuum* for the piston to descend, which is immediately brought down by the weight of the atmosphere. In its descent it shuts the *injection-cock* and opens the *regulator*, the steam again enters into the cylinder, and balancing the pressure of the air, the piston is raised by the weight of the pump rods at the other end of the beam, as it rises it shuts the *regulator* and opens the *injection-cock*, the stroke is again repeated, and the water in the pumps is raised and discharged at the top.

THE steam is seldom much stronger or weaker than the outward air, if it be $\frac{1}{15}$ stronger the engine will work well. At a mean the pressure upon every square inch of the piston will be 14 lb and and upon every square foot 18 cwt but in practice the weight at the other end of the beam should not be more than half the pressure upon the piston, in order that the *engine* may strike sufficiently fast.

THE *fire-engine* has lately been made with an *inverted piston*, to save the expence of a beam, the contrivance is ingenious, but it does not work any thing near so well as when made with a beam.

LECTURE V.

Of Electricity.

THE fourth species of *attraction* is that of electricity: If a globe of glass be turned round its axis, and rubbed with a cushion made of leather, covered with an amalgama of quicksilver and tin, it will attract all light bodies which lie near it, or within the sphere of attraction; which in dry weather extends to the distance of several feet. The electric fluid is collected, by the globe and cushion, from the earth; and may be communicated to any *insulated body* by means of a conductor. In electricity bodies are distinguished into *electrics* and *non electrics*, those which will collect the fire by rubbing, are called *electrics*, those which will not, *non electrics*.

If a tin tube, supported on glass, be connected with the globe in motion, it will receive more than its common share of electricity, but at the approach of a non electric, it will part with it again, with a snap and flash.

IF

IF a *pointed wire* be fixed in the tube and the room made dark, when the globe is turned the fire will issue out at the point in a fine diverging flame; if a non electric be laid upon the tube, as a finger &c. the flame will disappear, but if an electric be laid upon it, the flame will continue.

THE fire being once collected, may be transmitted to any distance in an instant, by means of a proper conductor insulated.

IF two bodies contain unequal shares of electricity, they *attract*, but if equal shares, they *repel* each other. If a cup of water be insulated and electrified, at the approach of a finger, the fire will snap from it, nearly with as much force as from the conductor. If wet sponge be electrified it will drop much faster than before, and the drops received in an insulated cup, will be electrical, whence it is evident the fire is carried down in the water.

A PIECE of leaf gold will be suspended between the conductor and the finger holden over it.

TAKE a phial almost filled with water and close corked, pierce a wire thro' the cork, and put it down into the water, then if a person grasp the phial in one hand, and hold the upper end of the wire to the conductor, the fire will be condensed in the water; if a finger of the other hand be applied to the conductor, the person will receive the eruption of fire, which will fly from the inside to the outside of the phial, to restore the *equilibrium*, and will give him a considerable shock, which will be felt about the joints and across the breast. The shock may be given to a number of people at the same time provided they join hands, or otherwise communicate with each other.

IF a person stand on a board supported by glass or baked wood, and communicate with the conductor by means of a wire &c. he will be all over filled with electrical matter, which at the approach of a finger will snap from any part of his body. If he hold his finger near warm spirits the spark will kindle the fumes and thereby set the whole on fire.

THE electric fluid seems to be inherent in all
bodies

bodies, except those called electrics; it is not only found diffused thro' every part of the earth, but also in the clouds, and when two clouds containing unequal quantities thereof, are brought near each other, by contrary winds or otherwise, it makes its appearance in a *flash of lightning*, flying from one cloud to the other, or if the electrified cloud be low it sometimes strikes to the earth, in which case it is called a *thunderbolt*.

THE fire may be brought down out of the clouds by a tall wire, or by a kite sent up with a wire twined in its cord. The *lightning* or *thunderbolt* generally strikes the highest objects, as the tops of hills, spires, chimneys, &c. therefore in *America* where they are subject to frequent storms of thunder, they, to prevent its dreadful effects, fix bars of iron up the ends of their houses, reaching from the ground above the highest part of the building, by which the fire is safely convey'd to the earth.

LECTURE VI.

Of Optics.

IT is manifest from a number of experiments that *light is a real substance or body of itself*, and that it consists of particles inconceivably small; otherwise they could not pervade the pores of glass, diamond, &c. The wisdom of the creator is abundantly manifest, and perhaps as fully displayed in the smallness of the particles of light, as in any part of the creation. Light is emitted from every point in the surface of a luminous body, in right lines, and with a velocity of 170,000 miles in a second of time, which is inconceivable and unparallel'd.

As light is propagated in straight lines, it must decrease, as the squares of the distances increase; *that is*, if at the earth we have a certain quantity or degree of light and heat from the *sun*, then at twice that distance there will be but $\frac{1}{4}$ part of that quantity, and at three times the distance but $\frac{1}{9}$ part thereof; but at half the distance there will be 4 times as much, and at one third of the distance 9 times

9 times as much: So it will be found that at *Mercury* there is about $6\frac{1}{2}$ times the light and heat that we have; at *Venus* near twice as much; at *Mars*, about $\frac{1}{3}$; at *Jupiter*, $\frac{1}{8}$; and at *Saturn*, $\frac{1}{16}$ part of the light and heat which we have.

IF a ray of light, coming from the surface of a luminous object, fall upon a plain mirrour, it will be so reflected that the *angle of reflection* will always be equal to the *angle of incidence*.

LIGHT, also, in passing out of one medium into another of different density is *refracted* or bent out of a streight line, and the more so as the medium is denser.

THE white light of the *sun* is *heterogeneous*, or of different kinds, and each kind has a different power of refraction, or is differently bent out of its way in passing thro' the same medium, and appears also of a different colour: These rays which are *least refrangible*, excite the idea of *red*; the second fort *orange*; the third *yellow*; the fourth *green*; the fifth *blue*; the sixth *indigo*; and the seventh *violet*.

IF

If a beam of the sun, coming thro' a small hole into a dark room, fall upon the side of a triangular glass prism, it will upon the opposite side of the room, form an oblong and coloured image of the sun.

Now if these different sorts of light were not differently *refrangable*, the image after refraction would continue to be round, but we find it is not, and that the red light is least, and the violet the most refrangible.

THAT these different kinds of light, or different colours really exist in the light of the sun, and that the image is not spread out by the incident rays being disturbed, shattered, or split by the glass, is evident from a number of experiments, as *shewn in the lecture*.

LIGHT falling upon the surface of bodies, is in part *reflected* and in part *imbibed*; if the parts of a body be so disposed as to reflect all the red rays, and imbibe the rest, that body will appear of a red colour; for every body must appear of the same colour of the light which it reflects to the eye; if
a body

a body reflect all the green rays and imbibe the rest, it must appear of a green colour &c, every body, therefore, appears of such a colour as would be produced by a composition of the different kinds of light which it reflects.

BODIES which reflect one kind of light and refract the others, will appear of different colours by refraction and reflection.

THE phenomenon of the *rain bow* is caused by the sun's rays being separated by the drops of falling rain, as is shewn in the lecture, by filling a glass globe with water, and letting a beam of the sun, coming thro' a small hole into a dark room, fall upon it.

IF parallel rays fall upon a *concave mirror*, they will be reflected back to a point, distant from the vertex of the mirror equal to half the radius of concavity, this is called the *solar focus*, or burning point; for the rays of the sun meeting in this point burn very intently; there is also in this point a perfect image formed of the object from whence the rays proceed; but if the object be brought nearer
so

so that the rays do not fall parallel, the image will not be formed in the focus, but further from the mirrour; and as the object is brought nearer, the image will recede 'till they meet in the centre of the sphere of concavity, where they will be of equal magnitude, but the image inverted.

As the object is brought nearer the focus, the image will constantly fly off, till the object arrive at the focus and then the rays will be reflected parallel among themselves, so that no image can be formed: If the object be between the focus and mirrour, the image will be formed behind the mirrour, erect and magnified.

PARALLEL rays falling upon a plain glass of equal thickness cannot be converged to a focus, but will proceed parallel after refraction.

If one side be plain and the other convex, parallel rays will be converged to a point, at a distance equal to the diameter of the sphere of convexity; if it be double and equally convex, they will meet in the centre of the sphere of convexity.

IN these points images will be formed of the objects

jects which the rays proceed from; if the objects be brought near, the images will be formed further from the glasses, than the above mentioned points.

If the distance of the object be equal to twice the focal distance of the glass, the image will be formed at the same distance on the other side, and of the same magnitude with the object, but inverted,

Concave glasses do not form images; but parallel rays, after refraction, proceed diverging as if they came from a point, distant from the glass, equal to the diameter of the sphere of concavity, if it be a *plano concave*; but as if they came from the centre, if it be a *double concave*.

THE *human eye* is of a globular form and consists of three *humours*, the *aqueous*, *crystalline*, and *vitreous*; parallel rays are by the *chrySTALLINE* humour converged to a focus at the bottom of the eye, where, if the eye be perfect, an image is painted of the object they proceed from, upon the *retina*, or optic nerve; but if the eye be too convex the rays will meet before they reach the retina; if too flat they will tend to a point beyond the retina;
the

the first is remedied by concave glasses, or by holding the object very near the eye, the last by convex glasses.

If an object be placed in the focus of a convex glass, the rays after refraction will proceed parallel among themselves, and an eye placed on the other side will have a distinct view of the said object, which will also appear to be magnified; for a perfect eye cannot see any thing distinctly nearer than 8 Inches, therefore if the focal distance of the glass be $\frac{1}{2}$ an inch, the apparent diameter will be increased 16 times, if $\frac{1}{4}$ of an inch 32 times; hence they become of use as magnifiers or *single microscopes*, for viewing small objects.

A *compound microscope* has a small object glass fixed in one end of a tube, and an eye glass in the other end, the object is placed upon a stage a little further from the glass than the focus of parallel rays, by this glass an image is formed of the object in the tube, and is as much magnified in length as the distance between the image and glass is greater than the distance between the object and glass, which suppose 8 times, then if the eye glass be one
inch

inch focal distance, the image by it will be magnified 8 times also, and by both glasses 64 times in length.

The magnifying power of the *solar microscope* is computed by dividing the breadth of the room by the distance between the object and glass: Suppose the first be 6 yards, and the last $\frac{1}{2}$ an inch, then will the object be magnified 423 times in length, 186,624 in surface, and 80,621,568 times in solidity.

The *camera obscura* or dark room, has a convex glass fixed in the top over which is placed a diagonal mirror, to throw the horizontal rays upon the bottom of the instrument, which is exactly in the focus of the glass, where, upon a sheet of white paper, the objects before the instrument are painted in the most lively and natural colours, when this instrument is used it is necessary that the objects be strongly illuminated by the sun.

A *perspective glass* has in one end a convex object glass, and in the other a concave eye glass: which is placed at its focal distance within the fo-

cus.

cus of the object glass: let the focal distance of the object glass be 6 inches, and that of the eye glass 1 inch, then the distance between them will be 5 inches; the magnifying power of this instrument is computed by dividing the focal distance of the object glass by that of the eye glass.

THE astronomical telescope has in one end an object glass by which the rays are converged to a focus where an image is formed of the object they proceed from; this image is viewed by an eye glass placed at its focal distance from it in the other end of the tube; and is as much magnified as the focal distance of the object glass is greater than the focal distance of the eye glass. All objects seen thro' this telescope appear inverted.

THE common *terrestrial telescope* has three eye glasses of the same focal distance, by which the image is viewed erect. Its magnifying power is computed the same way as the last.

IT is an imperfection in refracting telescopes that heterogeneous light is not refracted to the same point in the axis of the object glass; otherwise the
focal

focal distance of the eye glass might be very small and the magnifying power very great.

THIS imperfection is in part remedied in *Doland's patent telescope*, which is a great improvement of the common refracting one.

THE *reflecting telescope* is a wide tube open at one end, and in the other is fixed a concave mirror with a hole in the middle; rays of light falling upon this are reflected back and cross in its focus, after which, in a diverging state, they fall upon a small concave placed nearly at its focal distance from the focus of the great mirror, by which they are reflected back thro' the hole in the great mirror and fall upon a convex glass, by which they are converged to a focus and form an image, which is viewed by an eye glass in the end of the tube; this telescope magnifies 8 or 10 times as much as a refracting telescope of the same length.

THE *magic lantern* has a large convex glass in one side, and a candle being placed in its focus, the rays, after refraction, proceed parallel to each other, and illuminate a transparent painting; at a

F

distance

distance in the end of a tube is fixed another convex glass, by which the rays are converged to a focus and form an image of the painting, vastly magnified upon a white sheet on the side of a dark room.

LECTURE

LECTURE VII.

Of Mechanics.

THIS science treats of motion, explains the laws observed by moving bodies, and teaches how to compute the force of the mechanical powers, whether single or combined in machines: By this science the utmost improvement is made of every natural power, and the various elements made subservient to the purposes of man.

THERE are three laws which are observed by all moving bodies whatever.

THE first is, *That every body endeavours to continue in a state of rest, or moving uniformly in a right line.*

THE second is, *That the change of motion is always proportional to the generating force impressed, and is always made according to the right line in which that force is impressed.*

THE third is, *That action and reaction are equal, and in contrary directions.*

Of the descent of bodies in non resisting mediums.

A BODY left to itself, begins to descend or is carried towards the centre of the earth by the power of gravity; this power acts constantly upon all bodies in proportion to their quantity of matter; hence bodies containing unequal quantities of matter will descend with the same velocity. A body in one second of time will descend thro' a space of 16.13 feet, at the end of this time, were the attraction to cease, it has acquired a velocity which would carry it with an uniform motion over a space of 32.26 feet in the next second, but the attraction of gravitation acting constantly upon it, its motion continues to be accelerated, and it is carried over a space of 48.39 feet, or three times as far as in the first second. From hence it appears that falling bodies will be constantly accelerated, that the spaces fallen through will be as the squares of the times, or as the squares of the velocities, viz. if a body in a certain time fall thro' 16 feet, in twice that time it will fall thro' 4 times 16 feet, in three times the time thro' 9 times 16 feet, &c. the *momentum* of a falling body is always as the time or velocity; when the velocity is the same it is as the quantity of matter, and
is

is found by multiplying the quantity of matter by the velocity.

This is proved by letting a small weight fall from different heights upon the end of a scale beam, and raising weights suspended from the other end.

Of bodies descending down inclined planes.

As the length of the plane is to the height thereof, so is the space passed over by a falling body to the space descended thro' on the surface of the plane in the same time; and as bodies are carried down the inclined plane by the power of gravity, it is evident they will be equally accelerated as well as those which fall in perpendicular directions, that is, whatever space they pass over in one second of time, they will in two seconds pass over four times that space &c. and the velocity at the lowest point will be equal to that which would be acquired by a perpendicular descent thro' the altitude of the plane.

WHILE the altitude of the plane remains the same, the velocity at the lowest point will always be equal, whatever the length be; so that if a body

F 3

descend

descend down a number of contiguous planes, or down a curve, the velocity at the bottom, as also the *momentum* will still be equal. The times of descent down planes of the same altitude, but of different lengths, will be directly as the lengths.

FROM the above we may infer that whether a body descend thro' the diameter of a circle, or thro' any chord of the same circle, the descent will be performed in the same time; and the velocity at the lowest point will be equal to that which would be acquired by falling thro' the perpendicular height of the chord.

IF while a body descends down one chord, another falls thro' the diameter of the circle, then while it would ascend up the opposite chord, which would be in the same time, the falling body would pass over four times the diameter of the circle; the times of descent in arches are to those in their respective chords, as 1 to .7854, therefore the length of a pendulum to vibrate seconds will be found by the following process to be 39.2 inches; for as 1 (the square of 1 second) is to 16.12 feet, so is $\frac{1}{4}$ (the square of $\frac{1}{2}$ a second) to 4.03 feet,
the

the diameter of a circle in whose chord a body would descend and ascend in a second of time, its radius would be 2.01 feet; and as the descent in the arch is to the descent in the chord, as 1 to .7854 it will be, As the square of .7854, is to the square of 1, so is 2.01 feet, to 3.26 feet, = 39 2 inches. The lengths of pendulums are in the same ratio, as the squares of the times in which they vibrate, therefore to find the length of a pendulum to vibrate half seconds, say, As 1 (the square of 1 second) is to $\frac{1}{4}$ (the square of $\frac{1}{2}$ a second) so is 39.2 inches, to 9.8 inches, the length required. &c.

BODIES thrown in horizontal, oblique, or upright directions are called *projectiles*: Every projectile is acted upon by two forces, the *impetus* or *projectile* force and the *power of gravity*, by the first it passes over equal spaces in equal times, but by the second it falls thro' spaces which are as the squares of the times, every projectile, therefore, moves in a curve, except they be thrown upright, in which case, to appearance, they will move in a straight line.

EVERY body revolving round a centre is also

acted upon by two forces, the *centrifugal* and *centripetal*, the centrifugal arises from the first impulse, and tends to carry the body off from the centre. But by the centripetal force it is constantly drawn towards the centre. If these forces have a certain ratio to each other, the body is kept revolving round a centre in a circle or ellipsis.

IN revolving bodies we must observe the quantity of matter, the distance from the centre, and the periodical time, or time in which the body makes one revolution round the centre.

Two equal bodies revolving round a centre at the same distance and in the same time will have equal centrifugal forces.

If the distances and periodical times be equal, the centrifugal forces will be directly as the quantities of matter.

If the periodical times and quantities of matter be equal, the centrifugal forces will be in the same ratio as the distances.

If

If the periodical times be equal, and the distances be reciprocally as the quantities of matter, the centrifugal forces will also be equal.

When the distances and quantities of matter are equal, the centrifugal forces are directly as the squares, of the velocities, or reciprocally as the squares of the periodical times.

THESE laws are all demonstrated in the lectures by the *central machine*.

THE centre of magnitude is a point which is equally distant from every part of the surface. The centre of motion is that point which remains at rest, while all the outward parts of the body revolve round it. The centre of gravity is a point in every body, which, if sustained the whole body remains at rest. in uniform and homogenous bodies it is in the middle of a right line drawn between opposite angles, in a circle it is in the centre, in a triangle it is in a line drawn from an angle to the middle of the opposite side, one third of the length of that line from the side. From a knowledge of this centre we account for the phenome-

non.

non of the rolling cone, which seems to roll upwards between two inclined wires, *as shewn in the lecture*. Also for the cylinder which rolls up an inclined plane while the centre of gravity descends. From hence we also see the reason why some bodies stand more firmly on their bases than others; for while the perpendicular line which passes thro' this centre falls within the base of the body, it cannot fall, &c. If a number of bodies be connected together by a line, there will be a common centre of gravity among them, which, if supported they all remain at rest.

THERE are generally reckoned six mechanical powers, the LEVER which is the *first*, is of three sorts; the first has the *weight* at one end, the *power* at the other, and the *fulcrum* or *prop* between them. The second sort has the *fulcrum* at one, the *power* at the other, and the *weight* between them, The third sort has the *fulcrum* at one end, the *weight* at the other, and the *power* between them.

IN order to obtain an equilibrium in the lever, the power must always be to the weight, as the distance of the weight is to the distance of the power

power from the fulcrum; for then the product of the power multiplied by its distance, will be *equal* to the product of the weight multiplied by its distance, from the fulcrum, which is always the case when they balance each other: For bodies of unequal magnitudes can only balance each other when their *momentums* are equal; and this can only happen when their velocities are reciprocally as their quantities of matter.* The power of every kind of lever is computed by the same rules.

2. The WHEEL and AXIS.

IN this machine the power is applied to the circumference of the wheel, and the weight to the circumference of the axis; its force is computed by dividing the diameter of the wheel by the diameter of the axis.

3. The

* Let w = the weight
 p = the power
 d = distance of the weight
 n = distance of the power } from the fulcrum

Then as $p : w :: d : \frac{dw}{p} = n$, hence if any three of these be given the fourth may be found, for we have

$$n = \frac{dw}{p}, \quad p = \frac{dw}{n}, \quad w = \frac{pn}{d}, \quad d = \frac{pn}{w}$$

3. *The PULLEY.*

A SINGLE pulley if fixed, does not encrease the power: for it is evident the weight and power will pass over equal spaces in the same time; but in a combination where one part is fixed and the other moveable, the power will be to the weight, as unity to the number of ropes which come to the lower or moveable block: or however they be combined, the power will be to the weight, as the velocity of the weight to the velocity of the power.

4. *The INCLINED PLANE.*

THE inclined plane makes an oblique angle with the horizon; the length of the plane is the distance, upon its surface, between the lowest point and the highest: The altitude of the plane, is the perpendicular height from the horizontal line which touches its lowest point: If a body be to be sustained upon the inclined plane, the power will be to the weight, as the height to the length of the plane, or as the sine of the angle of elevation to the radius.

5. *The WEDGE.*

THE power of the wedge is the same as the
power

power of the inclined plane; for as the breadth of the head is to the length of both sides, so is the power to the resistance.

6. *The SCREW.*

THE force of the screw is computed by comparing the velocity of the weight with the velocity of the power; for suppose the distance of the threads be one inch, and the length of the lever to which the power is applied be 3 feet, then, in one revolution of the screw the weight will rise one inch, and the power will move thro' a space of 226.28 inches. From hence it appears that the power by such a screw would be increased above 200 times.

ALL these computations would answer very exactly were there no friction, but a very considerable part of the force is destroyed by friction, so that in loaded machines, engines, &c. we may deduct in some $\frac{1}{6}$ in others one $\frac{1}{3}$, $\frac{1}{4}$, or $\frac{1}{5}$ part of the whole effect.

ALL machines how ever complicated, are composed of the simple powers differently combined together, and the force or effect of the whole is found

found by computing the force of every seperate power, and multiplying the products together : As for *example*, in the common *crane*, suppose the length of the handle be 18 inches and the diameter of the nut 4 inches; if ten stone be applied to the handle, it will balance 90 at the circumference of the nut, for it is 9 times as far from the centre : Let the diameter of the great wheel be two feet, and the diameter of the axis 4 inches, then by this, the power will be increased 6 times, which multiplied by the last, will give 54, so that if 10 stone be applied to the handle, it will balance 10 times 54 or 540 at the axis.

LECTURE

LECTURE VIII.

Of Geography.

THAT the earth is of a globular form, is evident, from the shadow cast upon the moon in a lunar eclipse which is always terminated by a curve; by observing ships at sea and by sailing quite round it. Yet it has been found by measuring a degree of latitude at the equinoctial, polar circle, and several other parts, that the earth is not a perfect globe, but an oblate spheroid, being a little flattened at the poles; this also agrees with the theory of revolving bodies, for were the earth fluid, as it probably might in part, at the beginning, the parts under the equinoctial would be thrown further from the centre by the centrifugal force, which is there computed to be $\frac{1}{289}$ part of gravity. That the earth is not a perfect globe is also proved by the vibrating of pendulums; for it is found that a pendulum to vibrate seconds must be longer at the polar circles than at the equator: hence it is evident that the power of gravity is greater at the polar circles, and that they are therefore

therefore nearer the centre of the earth, for gravity increases as the square of the distance decreases.

HOWEVER the form of the earth is so near that of a perfect globe, that the difference in any instrument that can be made by art, would be imperceptible, and therefore a globe has been chosen by geographers, as the fittest instrument upon whose surface to delineate or lay down and describe, as near as can be done, the form of the various continents, islands, seas, gulphs, rivers, &c. so the terrestrial globe is an artificial representation of the habitable world in which we live, but in order to lay down or mark upon its surface, the various parts of the earth and seas in their natural order, distance &c. has put men under the necessity of inventing various lines and circles, which are described upon the surface of the artificial globe; for it was absolutely necessary to have some certain or fixed point to measure from, both to mark out the true places of the stars upon the celestial globe and to lay down the true form of the earth and seas on the terrestrial globe.

THESE which divide the globe into two equal
parts

parts are called *great circles*; these which divide it into unequal parts, *lesser circles*.

THE EQUATOR OR EQUINOCTIAL LINE, is a great circle which runs east and west quite round the globe, being every where at an equal distance from the poles, or axis round which the globe turns.

THE ECLIPTIC is that great circle in which the *sun* always appears to move, it cuts the equinoctial in two opposite points called *aries* and *libra*, and makes an angle with it of $23\frac{1}{2}^{\circ}$.

MERIDIANS are great circles which pass thro' the poles of the world, thro' the zenith and nadir, and cut the equinoctial line at right angles.

THE HORIZON is a great circle which bounds the spectator's sight in the heavens, and is every where equally distant from the place where he stands. On the artificial globe it is represented by a broad wooden circle.

THE COLURES are two meridians one of which passes thro' the beginning of *aries* and *libra*, and

G

and

is called the equinoctial colure; and the other thro' the beginning of *cancer* and *capricornus*, and is called the solstitial colure.

THE lesser circles are the two *tropics*, and the two *polar circles*. The *tropic of cancer* is $23\frac{1}{2}^{\circ}$ to the north, and the *tropic of capricorn* $23\frac{1}{2}^{\circ}$ to the south of the equinoctial, one bounds the sun's declination on the north, and the other on the south side thereof.

THE northern *polar circle*, called the *arctic circle* is $66\frac{1}{2}^{\circ}$ north of the equator, the southern or *antarctic circle*, is the same distance south of the equator.

THERE are two *frigid zones*, one is surrounded by the arctic circle, and the other by the antarctic circle.

There are also two *temperate zones*, one lies between the tropic of cancer and the arctic circle; the other between the tropic of capricorn and the antarctic circle. All that space which lies between the two tropics is called the *torrid* or *burning zone*.

THE inhabitants of the torrid zone are called
Amphiscii,

Amphiscii, because at noon they cast their shadows different ways at different seasons of the year.

THE inhabitants of the temperate zones are called *Heteroscii*, because their shadows at noon always fall one way.

THE inhabitants of the frigid zones are called *Periscii*, because in summer they cast their shadows quite round them.

THOSE who live under the same meridian, but have as many degrees south latitude as we have north, are called *Antiscii*, they have the same hour, their days are always the length of our nights, and their summer is our winter.

THE *Periæci* lie under the same parallel of latitude but differ 180° in longitude, their days and nights are always the same length of ours, their seasons are also the same, but they have the contrary hour or noon when we have midnight.

THE *Antipodes*, have as many degrees south latitude as we have north, and also differ 180° in

longitude, and consequently are directly under our feet, their day is always the length of our night, their summer is our winter, and they have noon when we have midnight.

A CLIMATE is such a space on the globe, that in summer, the longest day on the north side (if in north latitude) exceeds the longest day on the south side, by the space of half an hour. There are 24 climates on each side of the equator, between it and the polar circles; and six on each side between the polar circles and poles, where the length of the days on that side of the climate next the pole, exceeds the length on the other side by a whole month.

THE globe is divided into three different *spheres* those who live under the equinoctial have a *right sphere*, and have the poles in the horizon. A *parallel sphere* hath the equator in the horizon and all the circles of latitude parallel thereto. An *oblique sphere* hath one pole elevated above the horizon, and the other depressed below it.

LATITUDE

LATITUDE of a place is its distance north or south, from the equator.

LONGITUDE is the distance between the meridians of any two places, and is counted upon the equator.

THE ZENITH, is that point in the heavens which is directly over our heads.

THE NADIR is that which is diametrically opposite, or right under our feet.

A CONTINENT is the largest division of land comprehending various *countries, empires, and kingdoms* not separated by water.

AN ISLAND is a small tract of land entirely surrounded by water.

A PENINSULA is a part of land all surrounded by water, except a narrow neck, called an

ISTHMUS, by which it is joined to the continent.

G 3 A PROMONTORY

A **PROMONTORY** is a mountainous part of land standing far into the sea.

THE OCEAN is the largest collection of waters, it lies between and environs the continents.

A **SEA** is a smaller part of the ocean which goes between the continents.

A **GULPH** is a part of the sea every where encompassed with land except one small part called a

STRAIT, which is that narrow passage by which it is joined to the adjacent sea.

A **LAKE** is a large quantity of stagnant water entirely surrounded with land.

THE whole surface of the globe contains near 200 millions of square miles; the inhabited part 39 millions, the sea and unknown parts 161 millions; from whence it appears that there is more than 4 times as much water as land upon the surface of the globe.

LECEURE

LECTURE IX.

Of Astronomy.

ASTRONOMY is that Science which discovers to us the true motions, magnitude, distances, eclipses, and other appearances of the heavenly bodies. In the *Solar System*, which is composed of the sun, 6 primary, and 10 secondary planets, besides comets, the sun is placed in the centre, and the planets revolve round him from west to east, at different distances and in different periods; as in the following table.

	Distances in Miles	Periods.	Diurnal Revolutions.	Diameter in Miles.	Velocity per Hour in Miles
		Y. D. H..	D. H.		
Mercury	36	87 23	unknown	3,000	109,700
Venus	68	224 17	24 8	9,000	80,300
Earth	95	1 0 0	1 0	7,970	68,200
Mars	145	1 32 17	1 0 $\frac{3}{4}$	5,150	55,000
Jupiter	494	11 315 0	0 1	94,000	29,000
Saturn	907	29 167 0	unknown	78,000	22,000

THE space in which the planets move seems to be void of all matter which can afford resistance, for doubtless they continue to move with the same velocity which they had at the beginning, which, according to the laws of nature, they could not do if they were resisted; for the planets are constantly acted upon or kept moving round the sun by two powers; one is the centripetal force or attraction of the sun, by this they are constantly acted upon and drawn towards the sun's centre: The other is the centrifugal or projectile force by which they endeavour to fly off in tangents to their orbits. The projectile force which remains the same was communicated by the creator at the beginning, and as the attraction of the sun at every planet is different, so is the centrifugal force, for it is necessary that they have a certain ratio to each other in order to keep the planets revolving in orbits nearly circular. Comets move round the sun in orbits vastly excentric, and like the planets always describe equal areas in equal times, for as they approach the sun, their velocity increases inversely with the square of the distance. The diameter of the sun is 893,760 miles, it turns round its own
axis

axis, which makes an angle of 8 degrees with the ecliptic, in something less than 26 days.

JUPITER has four moons whose orbits lie nearly in the plane of the ecliptic, they revolve round him from west to east, the first at the distance of 5.6 semidiameters in 1 day 18 hours and 27 minutes; the second at the distance of 9 semidiameters in 3 days 13 hours and 13 minutes; the third at the distance of 14.2 semidiameters in 7 days 3 hours and 49 minutes; the fourth at the distance of 25.3 semidiameters, in 16 days 16 hours and 32 minutes: This planet is also surrounded with cloudy dark streaks commonly called his belts, but what they are is at present unknown.

SATURN is attended with five satellites or moons, the first at the distance of 2 semidiameters, revolves in 1 day, 21 hours, and 18 minutes; the second, at the distance of 2.4 semidiameters, revolves in 2 days, 17 hours, and 41 minutes; the third, at the distance of 3.6 semidiameters, revolves in 4 days, 12 hours, and 25 minutes; the fourth, at the distance of 8 semidiameters, revolves in 15 days, 22 hours, and 41 minutes; the fifth at the

the distance of 23.3 semidiameters, in 70 days, 22 hours, and 4 minutes: besides these moons *Saturn* is also encompassed with an amazing *phenomenon* called his *ring*, the diameter of which is computed at 120,000 miles; this *ring* is inclined to the plane of the ecliptic, about 31 degrees, its nodes are in 19 degrees and 45 minutes of *Virgo* and *Pisces*; when *Saturn* is in those signs the plane of the *ring* passes thro' the earth, it will therefore be invisible, or appear like a straight line upon the disk of the *planet*, but when *Saturn* is in *Gemini* and *Sagittarius*, the *ring* will be most open, and in the best position to be viewed.

THERE have been other two hypothesis invented to account for the celestial appearances, called the *Ptolomaic*, and *Tychonic systems*; but in the lectures they are shewn by the planetarium, to be insufficient to account for the *phænomena*, and therefore exploded; and the *Copernican* proved by unanswerable arguments and demonstrations, to be the true system of the world.

As all the planets are retained in their orbits by the attraction of the sun, so is the moon by the attraction of the earth; the earth and moon mutually

tually attract each other in proportion to their quantities of matter; by this power they are connected, and between them there is a common centre of gravity, * at the distance of 1218 miles from the earth's surface, it is this centre that describes the great orbit round the sun, and not the earth itself, for both the earth and moon revolve round this centre once a month; hence it is evident that the earth will be near 11,000 miles nearer the sun when the moon is full, than when she is changing.

As the attraction of the moon reaches to the earth, the waters on that side next the moon must be rendered lighter, and therefore stand at a greater distance from the centre, than on any other part of the globe; while on the opposite side the attraction

of

* The distance of this centre is found as follows,
 Let e = the quantity of matter in the earth = 45.
 m = the quantity of matter in the moon = 1.
 a = the distance between the earth and moon = 240,000
 x = the distance between the centre of the earth and the centre of gravity,

Then (per mechanics) we shall have $ex = ma - mx$; and

$x = \frac{ma}{e + m}$, viz. if the quantity of matter in the moon, be multiplied by the distance between the earth and moon, and that product divided by the sum of the quantities in the earth and moon, the quotient will be the distance from the earth's centre = 5,218 miles.

of the moon must conspire with the attraction of the earth and cause the waters to sink lowest, therefore were the waters affected by nothing but the moon, we should have one flood and one ebb in 25 hours; but as the earth is constantly revolving round the centre of gravity, the waters receive a centrifugal force, which, on that side next the moon is to that on the opposite side as 1 to $7\frac{1}{2}$ which is the cause of two tides in 25 hours, for at the earth's centre, the centrifugal force and attraction just ballance each other; on that side next the moon the attraction is greater, but on the other side the centrifugal force is greater.

THE attraction of the sun partly diminishes the gravity of the waters, and therefore, at the full and change when it conspires with the attraction of the moon the tides rise highest.

THE EARTH in one day turns round its own axis, and in one year is caried round the *sun*, with its axis inclined to the plane in which it moves, making an angle therewith of $66\frac{1}{2}$ degrees, and always retaining their parallelism, by which means the poles are alternately turned towards the sun.

When

When the earth is in *libra* the sun appears in the equator, and the circle of illumination passes thro' the poles of the world, the days and nights are now of an equal length on every part of the globe. But while the earth moves from *libra* to *capricornus*, the north pole will constantly turn towards the sun and the south pole from it, during which space the days in northern latitude are constantly increasing and the nights decreasing: When the earth comes to the beginning of *capricornus* we have the longest day and shortest night, and the sun appears in the opposite sign *cancer*; at this time the whole northern frigid zone is illuminated, and the southern obscured in darkness; the circle which divides between the light and dark hemisphere, just touches the polar circles, so that at every place, except the equinox and poles, the days and nights are of unequal lengths. After the earth has passed the beginning of *capricornus*, the north pole begins to turn from the sun, and the south pole towards it. The days in northern latitude, again begin to shorten, and in southern latitude to lengthen; when the earth comes to the beginning of *aries* the poles are equally distant from the sun, the circle
of

of illumination again divides all the parallels into equal parts, and the days and nights are every where of an equal length. As the earth moves forward from *aries* to *cancer* the days, in northern latitudes, will continue to shorten, and in southern latitudes to lengthen, When the sun appears in the beginning of *capricornus*, which happens when the earth arrives at the beginning of *cancer*, the days in northern latitudes are of the least length, and the nights of the greatest, at which time we have the middle of winter, the whole northern frigid zone is now obscured in darkness, and the southern frigid zone all illuminated. When the earth has passed this point, the north pole will gradually turn towards the sun, and the south pole from it, the days constantly increase and nights contract, while the earth moves thro' that half of the ecliptic. When the earth comes to the first point of *aries*, it has made one revolution round the sun, the days and nights, as at first, are now equal all over the earth; whence the cause of the different seasons, and different lengths of days and nights is evident. *Explained by the Orrery.*

THE 12 signs of the Ecliptic are

Northern Signs.

Aries,
Taurus,
Gemini,
Cancer,
Leo,
Virgo,

Southern Signs.

Libra,
Scorpio,
Sagittarius,
Capricornus,
Aquarius,
Pisces.

THE orbit of the moon makes an angle of 5 degrees and 20 minutes with the plane of the ecliptic, and intersects it in two opposite points called nodes, one of which is called the *dragon's-head*, and the other the *dragon's-tail*, when the moon is in these points or nodes she has no latitude, but when she is in any other part of her orbit she is said to have north or south latitude according as she is north or south of the ecliptic; in the *orrery* the moon is carried round by a syderial plate, on which are engraved the signs of the ecliptic; on another plate is also engraved her age, the distance from her nodes and latitude; by which when the *orrery* is rectified, her age, place in the ecliptic, distance from her nodes and latitude, are,
for

for any day pointed out. The *nodes* of the moon do not remain fixed in the same part of the ecliptic, but have a retrograde motion and make one revolution in $18\frac{3}{4}$ years; this motion of the nodes is the cause of various phenomena; it is owing to this, that the moon, once in 19 years, goes further both north and south than at any other time, and that the eclipses always happen at different seasons of the year, &c.

THE moon, like all the planets in the system, is an opaque or dark body, and shines upon the earth by reflection from the sun, therefore, as the moon is constantly moving round the earth, it is evident that, when she is between the earth and sun, her dark side will be turned towards the earth, and she will be invisible; as she moves from conjunction her illuminated side will gradually turn towards the earth, 'till she be opposite to the sun, when she will appear full; after which time she will again constantly decrease, 'till the conjunction or change, *as is evident by the orrery.*

WHILE the moon makes one revolution round the earth, she also turns once round her axis, and
of

of consequence still keeps the same side towards the earth, so that a spectator in the moon would always see the earth, which is a *moon*, to the moon, in the same part of the heavens, and it would appear, when full, about 13 times larger in surface than the full moon appears to us. As the moon only turns once round her axis in a lunation, one lunar day and night will be the length of $29\frac{1}{2}$ of ours. The moon in the space of $27\frac{1}{3}$ days moves thro' all the signs of the ecliptic or quite round the earth; this is called the syderial day, the reason that she is not again in conjunction with the sun is owing to the earth's progressive motion in its orbit, by which the sun appears to have moved thro' near a whole sign to the east, so that the moon will yet require about $2\frac{1}{6}$ days to come up with the sun, which space of time is called the difference between her periodical and synodical revolutions, or between her solar and syderial day.

THE moon some days before and after the change appears cusped, and the position of these cusps at different times of the year is very different; but always the same at the same season, *as is shewn by the globe.*

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THE

THE different angles which different parts of the ecliptic make with the horizon, when rising, is the cause of that phænomenon we call the harvest moon; *virgo* and *libra* make the greatest angle; *pisces* and *aries* the least, so that in a given time, a greater length of the ecliptic rises in these signs than in any other, and did the moon move in the ecliptic she would rise about 26 minutes later every night for 6 nights together; but as the orbit of the moon does not lie in the plane of the ecliptic, she will sometimes rise with less difference of time, and sometimes with more. For when her north node is in *aries* and her south node in *libra*, her orbit will make the least angle with the horizon, at the rising of *aries*, that can be; in this latitude it will not be more than $7\frac{1}{6}$ degrees, and she will rise for 6 nights within 1 hour and 35 minutes of the same time, or she will be about $\frac{1}{4}$ of an hour later of rising every night; but she will differ 1 hour and $\frac{1}{4}$ every morning in her setting.

WHEN the south node is in *aries*, and the north node in *libra*, the harvest moon will be least advantageous, she will differ near twice as much in her
 rising

rising, as she did in the last position of her nodes; the reason whereof appears plain by the *orrery*.

THE moon rises with the same difference of time once in every lunation, as she does in harvest, but then, as this does not happen at the full moon, at any other time of the year it is not much noticed. The north node will not be in the beginning of *aries* before the year 1783, when we shall have the harvest moons to the greatest advantage, as also for two years before and after.

AT the equinoctial they have no harvest moon, for nearly an equal quantity of the ecliptic always rises in the same time; but as the latitude increases the angle which the ecliptic makes with the horizon at the beginning of *aries* gradually decreases 'till we come to the polar circle, where there is no eastern angle, and of consequence one half of the ecliptic rises at the same time, in this latitude the moon does not differ more than 1 hour in her rising for 15 days but is 23 hours later in her setting.

AN eclipse of the sun is caused by the moon

H 2

coming

coming between the sun and the earth, and is either total or partial; in like manner, an eclipse of the moon is caused by the earth intervening, or coming between the moon and sun; so that the moon looses her light in passing thro' the earth's shadow. If the orbit of the moon were in the same plane with the orbit of the earth, there would be an eclipse of the sun at every new moon, and an eclipse of the moon at every full; but this is prevented by the latitude of the moon, except she be within 12 degrees 2 minutes and 9 seconds of the node at the time of the full, or within 18 degrees and 20 minutes at the time of the change, which distances are called the limits. The nodes, which almost retain their parallelism, only come in a line with the sun twice in a year, and therefore there can only be two ecliptic seasons in one year; the limits are not always the same, owing to the different distances of the sun and moon from the earth, at different times; when the solar limit is least the sun will pass over it in 28 days, and when greatest in 32 days, in which time the moon may come twice in conjunction with the sun, and so cause two small eclipses; however in every solar limit there is one eclipse very certain. When the lunar
limit

limit is least the earth's shadow will pass over it in 19 days, and when greatest in about 24 days, so that the moon cannot be eclipsed more than once, but may, and often does pass the limit without suffering an eclipse.

THE earth has a third motion, whereby the pole of the world is constantly moving round the pole of the ecliptic, by this motion the equinoxes fall 50 seconds sooner every year, than the year before, and the fixed stars, by it, appear to move 1 degree eastward in 72 years; since observations have been made upon the stars, they have moved thro' almost a whole sign, for the constellation which was once in *aries*, is now in *taurus*; and the constellation of *taurus* is now in *gemini*; by this motion the seasons are constantly moving backward or in *antecedentia*, and would make one revolution in 25,920 years; were the world to continue 12,960 years, the longest day would fall on the 23d of December, and the shortest or mid-winter in June.

ALL the stars which are visible in the heavens, except five planets, are called, *fixed stars*, and are fixed in the same part of absolute space; the mo-

tions which they seem to have are caused by the motion of the earth; for it is evident, if the earth turn round its axis in 24 hours from west to east, that they must appear to move from east to west. The fixed stars are at immense distances from the earth or sun; were a body to fly from the sun with a velocity of 8 miles per minute, which is about as swift as a cannon ball, it would arrive at the orbit of mercury in $8\frac{3}{4}$ years; at venus in $16\frac{1}{2}$ years; at the earth in $22\frac{3}{4}$ years; at mars in $34\frac{1}{2}$ years; at jupiter in $117\frac{3}{4}$ years, at saturn in $215\frac{3}{4}$ years; but it is supposed it would not reach the nearest of the fixed stars in less than 700,000 years; however, their distance is utterly unknown, being immeasurable and unconcievable. It is supposed that the different degrees of brightness or splendor which we observe amongst the stars is owing their different distances from us, and not to any difference in their magnitude; for it is most likely that they are equally distant from each other, as they are from the sun. The fixed stars shine by their own native or unborrowed light, and are innumerable, for by a telescope thousands may be seen which are invisible to the naked eye; we cannot therefore suppose that these unseen stars were placed in
the

the heavens in order to supply the inhabitants of the earth with a faint light in the night, for which purpose some think the rest of the stars were made, neither can we suppose that they were made to declare to the earth the greatness and power of the creator, because very few of the race of mankind have seen them or heard of their existance; neither can we think that the almighty has created any thing in vain; but we may reasonably conclude that they are suns or fountains of light, illuminating systems of planets whose motions are controuled by their attractive power, and that the stars which are invisible to the inhabitants of the earth proclaim the glory and wisdom of the deity to other intelligent beings dwelling in worlds placed far beyond the utmost bounds of our sight. This hypothesis displays the greatness and dominion of the divine being; this confines not the creation within the narrow bounds of the sphere of fixed stars, but supposes it extended thro' the regions of unmeasurable space.

THIS wide machine the universe regard,
With how much skill is each apartment rear'd?

The SUN a globe of fire, a glowing mass,
 Hotter than melting flint or fluid glass.
 Of this our system holds the middle place,
 MERCURY the nearest to the central sun,
 Does in an oval orbit circling run;
 But rarely is the object of our sight,
 In solar glory sunk and more prevailing light.

VENUS the next whose lovely beams adorn
 As well the dewy eve as opening morn,
 Does her fair orb in beauteous order turn.

The GLOBE TERRESTRIAL next with slanting
 poles

And all its pond'rous load unwearied rolls.

MARS next in order, further from the sun,
 Does in a more extensive orbit run.

Then we behold bright planetary JOVE
 Sublime in space, thro' his wide province move;
 Four second planets his dominion own,
 And round him turn, as round the earth the moon.
 SATURN, revolving in the highest sphere,
 Is by five moons attended thro' his year.
 The vast dimension of his path is found,
 Five thousand million English miles around.

YET is this mighty system, which contains
 So many worlds such vast ætherial planes,

But

But one of thousands, which compose the whole,
Perhaps as glorious, and of worlds as full.
The stars which grace the high expansion, bright,
By their own beams and unprecarious light,
Tho' some near neighbours seem, and some display
United lustre in the milky way,
At a vast distance from each other lie,
Sever'd by spacious voids of liquid sky.
All these illustrious worlds and many more,
Which by the tube astronomers explore;
And millions which the glass can ne'er descry
Lost in the wilds of vast immensity,
Are *suns*, are *centres*, whose superior sway
Planets of various magnitudes obey.

If we with one clear comprehensive sight
Saw all these systems all these orbs of light;
If we their order and dependence knew,
Had all their motions and their ends in view,
With all the comets which in ether stray,
Yet constant to their time and to their way,
Would not this view convincing marks impart
Of perfect wisdom and stupendious art.

Blackmore.

An
EXPLANATION,
 Of Technical Words, Terms, &c. used in the
 foregoing LECTURES.

A.

*A*CID, sour, sharp.

Accumulate, to heap up, to gather together.

Adhesion, a cleaving, or sticking to.

Alkaly, a fixed salt, or substance that will ferment with an acid.

Ambient, encompassing,

Analogy, ratio, proportion,

Apperture, an opening, hole, &c,

Apelion, that point in a planet's orbit which is farthest from the sun.

Apparatus, instruments for performing experiments, &c.

Atmosphere, the air.

C.

Capillary tube, a tube with a bore as small as a hair.

Central, of or belonging to a centre.

Circumambient, surrounding on all sides.

Cohesion, sticking together.

Compress, to press together.

Concave, hollow.

Concentric, that have the same centre.

Condense, to make thick or close.

Conjunction, a meeting of two planets &c. in the same degree

Contact,

Contact, touching each other.

Convex, round, protuberent, like the surface of a globe.

Convergent, tending to, or meeting in one point.

Counterpoise, to balance.

Cusps, the horns of the moon &c.

D.

Descent, a going down.

Dichotomised, dissected, divided into two equal parts.

Disk, the visible surface of a planet &c.

Diurnal, daily, belonging to the day.

Divergent, spreading or separating.

E.

Ebullition, boiling, &c.

Eclipse, a deprivation of light.

Effervescence, waxing or growing hot.

Efluvia, the very small particles emitted from bodies.

Elastic, springy.

Ellipsis, an imperfect circle, an oval like figure.

Emersion, a rising out, or appearing again.

Epitome, an abstract or shortening.

Epocha, or *Æra*, a fixed point of time from whence the succeeding years are numbered.

Equilibrium, an even balance.

Evaporate, to exhale, or resolve into vapours.

Excentric, that hath different centres.

Exhaust, to draw out, or empty.

Expansion, swelling, or increasing in bulk.

Explosion, a noise or report.

External, outward.

F.

F.

Fibre, small threads or filaments,

Flaccid, loose, not tight.

Focus, that point where all the rays of the sun which fall upon a concave mirror, or lense, are collected.

G.

Gibbous, round, convex, or bunched out.

H.

Halo, a circle appearing round the moon &c.

Hemisphere, half of a globe or sphere.

Heterogeneal, of different kinds, or sorts.

Homogeneal, of the same sort.

Horizontal, level, parallel to the horizon.

Hypothesis, a supposition &c.

I.

Imbibe, to absorb, or drink in.

Immerse, to immerse, or plunge in water.

Immenfe, infinite.

Impetus, a blow, or impulse.

Incidence, a falling upon.

Insulated, supported by an electric substance.

Interstices, a distance or space between.

Irradiate, to shine upon, or enlighten.

L.

Lateral, of or belonging to the side.

Lense, a glass ground convex.

Longitudinal, lengthways.

M.

Medium, that peculiar constitution of any space or region thro' which bodies move.

Me-

Mepbetic, noxious.

Momentum, the whole force with which a moving body strikes against another in its way.

N.

Nocturnal, of or belonging to the night.

Noxious, poisonous, destructive.

Nubilous, cloudy, gloomy.

Nucleous, the head of a comet, &c.

O.

Oleaginous, oily, or full of oil.

Opaque, dark, shady.

Orbit, the path of a planet or comet.

Orifice, a hole, apperture, or mouth.

P.

Particles, the smallest parts of matter.

Percussion, a striking.

Peribolion, is that point in a planet's orbit which is nearest to the sun.

Perforate, to bore, or pierce thro'.

Phases, the different appearances of the moon, &c.

Phænomenon, signifies an appearance, effect, or operation of a natural body.

Preponderate, to outweigh.

Projectile, a body thrown or projected from the earth.

R.

Ratio, reason, proportion.

Rarefy, to make thin.

Recipient, a glass receiver for the air pump.

Reflection, a beating back.

Refraction,

Refraction, turning aside, or out of a streight line.

Refrangible, capable of being refracted.

Reservoir, a place for water.

Retrogradation, a going backward.

S.

Saturated, filled.

Sluice, a flood gate, a drain.

Subterraneous, under ground.

Syzygia, the conjunction and opposition of a planet with the sun.

T.

Tangent, a straight line just touching the circumference of a circle.

Tension, a bending or stretching.

Transit, a passing over, or crossing.

V.

Valve, a kind of lid or cover, letting a fluid pass one way but not the other.

Velocity, celerity swiftness.

Vertex, the top of any thing.

U.

Universe, the assemblage of heaven and earth, or of all created beings.

F I N I S.



